Universalization as a physical guiding principle

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Abstract

In this essay, I wish to share a novel perspective based on the principle of universalization in arriving at the relativistic and quantum world from the classical world. I also delve on some insightful discussion on going "beyond".

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I. THE NEWTONIAN WORLD

In the classical Newtonian World, we have the absolute 3-space and the absolute 1-time with space having the Euclidean flat metric. Then there are the three laws of motion governing motion of particles. The laws however apply only to massive particles. That is massless particles cannot be accommodated in the Newtonian mechanics. If such particles exist in nature, they would ask for new mechanics. The characteristic of such a particle is that it can't exist at rest in any frame because its mass is zero. It should be moving relative to all observers and its speed must be the limiting speed. No observer can attain this speed else it could have it at rest. That is, its speed must be the same constant for all observers and hence it is a universal constant.

On the other hand we also know in the Newtonian framework that light always moves in a straight line in all directions. The straight line motion is indicative of constant speed. Not quite, there could occur accelerated motion in straight line for force acting along the line of motion. Since light moves straight in all directions, this possibility is also ruled out because there cannot exist a force acting in all directions. We are thus forced to conclude that either Newton's laws of motion do not apply to light or its speed must be constant. This constant should be the same for all observers because light moves in a straight line for all observers. That is, light's speed must also be a universal constant.

It is Maxwell's electrodynamics which establishes that massless particles do in fact exist in nature. Photons, particles of light, are indeed massless. We should thus have a new mechanics which incorporates massless particles as well in its fold. That is to incorporate a universal constant speed. It is the universality of laws of motion which asks for a new mechanics respecting universal character of the speed of light.

Under Newton's law of gravitation, all massive particles attract each other by the inverse

square law and again there is no prescription for zero mass particles. That is, it does not incorporate massless particles in the gravitational interaction. Gravity is on the other hand a universal force as it links to all particles and "pulls" them all with the same acceleration irrespective of their mass and constitution. Linking of gravity is universal and hence it must also link to massless particles which however could not be accomplished in the Newtonian theory. Thus universality of the gravitational force asks for a new theory of gravitation.

The most fundamental universal entities are space and time and hence any universal property must always be expressible as a property of space and time. Even in the Newtonian mechanics, free particles move in straight lines which are geodesics (shortest distance or autoparallel curves) of the 3-Euclidean space. The geodetic motion is a universal property of free particles, their motion does not depend upon the specific particle parameters. Also the motion under gravity is independent of mass of the particle. It indicates that a full realization of the universal character of gravitation would ask for its becoming a property of space and time. That is in a new theory, gravitation must cease to be an external field but instead be completely synthesized in the space-time geometry.

The guiding principle that thus emerges is that a universal property must always be expressible as a property of spacetime.

II. THE RELATIVISTIC WORLD

The universalization of the Newtonian mechanics which includes massless particles (which is in turn equivalent to incorporation of a limiting universal invariant speed) naturally leads to the new relativistic mechanics, special relativity (SR). It synthesizes space and time into a 4-dimensional spacetime manifold having the flat Minkowski geometry. The universality of invariant light's speed gets synthesized in the definition of spacetime geome-

try specified by the Minkowski metric.

The next question is of universality of gravitational field. Like the laws of mechanics are universal (and thus must apply to all particles), so must be the case for gravity. It is universal and hence must act on all particles including particles of zero mass. The massless particles always have fixed speed relative to all observers. Within the Newtonian framework, action of force should in general change particle's speed but that can't happen for massless photons. We are thus faced with the real contradiction which can only be resolved by doing something very drastic and unusual. What is really required is that photon path like other particles path should instead of going straight bend toward the gravitating body as it grazes past it. This could happen without changing photon's speed only if gravitational field due to the body must bend space around it. That is gravity bends/curves the space around a gravitating body. Since space and time have already been synthesized, gravitational filed must hence curve spacetime. We thus come to a very revolutionary conclusion that universality of gravitation demands that it could honestly be described by nothing else but the curvature of spacetime.

Thus universality of gravitation does not let spacetime remain inert background but instead impregnates it with dynamics, a unique and distinguishing property. It then ceases to be an external field and is fully integrated into the geometry of spacetime and motion under gravity would now be given by the free geodetic motion relative to the curved geometry of spacetime. The equation of motion for gravitational field does not have to be specified from outside but should by itself follow from the curvature of spacetime. The curvature of spacetime is given by the Riemann curvature tensor which satisfies the Bianchi differential identity. The contraction of which yields the second rank symmetric tensor, constructed from the Ricci tensor, having vanishing divergence. That is,

$$\nabla_b G^{ab} = 0 \tag{1}$$

where

$$G_{ab} = R_{ab} - \frac{1}{2}Rg_{ab}\,. \tag{2}$$

The above equation implies

$$G_{ab} = -\kappa T_{ab} - \Lambda g_{ab} \tag{3}$$

with

$$\nabla_b T^{ab} = 0 \tag{4}$$

where T_{ab} is a symmetric tensor, and κ and Λ are constants. The demand that it should in the first approximation reduce to the Newtonian equation for gravitation will require T_{ab} to represent the energy momentum tensor for matter and $\kappa = 8\pi G/c^2$ with Λ being negligible at the stellar scale. This is the Einsteinian equation for gravitational field, general relativity (GR). [1,2]

Note that the constant Λ enters into the equation naturally. It was first introduced by Einstein in an ad-hoc manner to have a physically acceptable static model of the Universe and was subsequently withdrawn when Friedmann found the non-static model with acceptable physical properties. This kind of birth gave it the name cosmological constant studded with ambiguity and arbitrariness about its existence. We would however like to maintain that it appears in the equation as naturally as the stress tensor T_{ab} and hence should be considered on the same footing. What its value is to be determined by observations.

Let us imagine, had Einstein followed the path we have done above, he would have concluded that space free of all removable matter/energy ($T_{ab} = 0$) is indeed endowed with non-trivial dynamics given by the stress tensor, Λg_{ab}. This is precisely the stress tensor of virtual particles produced by the quantum fluctuations of vacuum [3]. He would have then anticipated that vacuum may have non-trivial quantum properties and its energy momentum is given by the new constant Λ. Thus Λ comes in naturally as the measure of vacuum,

a new constant of the Einsteinian gravity, a purely of general relativistic entity. This would have been a new prediction. Instead of Λ being the greatest blunder of his life, it should have really been a profound prediction anticipating the quantum aspects of vacuum and its gravitational interaction. This all happens simply because Einstein's equation refers to the spacetime in its entirety. Hence whatever happens or could happen in spacetime must be contained in the equation. Since spacetime is all inclusive, nothing could be shielded from it. It is again the reflection of the universality of gravitation and spacetime.

III. ANOTHER VIEW OF GRAVITY

Let us envision that all particles massive as well as massless share a universal interaction without reference to gravity. That would imply that the interaction has to be long range and it can not be shielded or removed globally. Since it is shared by massless particles as well, the equation of motion describing motion under it would have to be free of mass of the particle. That would mean that it could however be removed locally because all particles in the local neighborhood would follow the same path. Then the interaction in question could only be removed locally but not globally. There could thus exist only local inertial frames (LIFs) but no global inertial frame (GIF).

The non-existence of GIF and existence of only LIFs imply that spacetime has to be curved with its curvature being given by the Riemann curvature tensor. Once we have hit upon the Riemann curvature, we could follow the above line of derivation to get to the equation (3). This is now the equation of motion for the universal field. It is a second order non linear differential equation in the metric potentials, g_{ab}, and thus on the right it should have the source for the field. The second rank symmetric tensor T_{ab} should then describe the source of the field. Since the interaction is universal, its source should be the property which is shared by all particles. That could only be energy of particles, and hence

T_{ab} should represent energy momentum tensor of matter. Then the equation becomes the Einstein equation for gravitational field which we have derived simply by using the universal character of the interaction. The envisioned universal interaction could therefore be nothing other than gravitation. This is quite remarkable that the universality property of interaction uniquely singles out gravity. That means gravitation is the unique universal field in the classical framework.

Another example of a dynamical property determining dynamics of force is Bertrand's theorem for central forces in classical mechanics [4]. The demand of existence of closed orbits picks out two force laws, Hooke's law giving simple harmonic motion and the inverse square law. Further the demand of long range would then single out the latter. Here we refer to the most general property of universality of force which not only determines the dynamics of the force completely and uniquely but it does so in a very extraordinary manner by making the spacetime itself dynamic [1]. This happens because a universal feature could only be answered through a universal entity, spacetime. Since universality refers to a force, hence the answering universal agency must endow the dynamics of the force.

IV. YET ANOTHER VIEW

Gravity is a classical field and hence it is a valid question to ask for its charge/source and the answer is matter/energy in any form. Non gravitational matter/energy is always positive which means it has only one kind of polarity and hence it can never vanish. That is a body can never be gravitationally neutral. From a classical standpoint, a body which is not charge neutral cannot be stable for it must keep on accreting until it neutralizes. For gravity, this can't happen for any further accretion leads to increasing rather than neutralizing charge. The only way this situation could be made sensible is that gravitational field energy must possess charge and it should have opposite polarity than that of non gravitational energy.

That is why gravitational field energy must be negative and hence the field attractive. The field energy is however not localizable and therefore there is inherent ambiguity in its definition and that is why there exist several expressions for it in the literature [5,6]. Each of them brings out some aspect or the other. The main cause of ambiguity is the nonlocal or quasilocal character of gravitational field energy.

If we want to include gravitational field energy as a source, we have, rather than the usual Laplace equation for empty space, the Poisson equation with the field energy density on the right hand side. Its solution would now violate the inverse square law which is required by the conservation of charge for a spherically symmetric source. We thus end up in a contradiction similar to light's propagation in gravitational field. That is, we shouldn't violate the celebrated inverse square law and yet the contribution of gravitational field energy should be included. We have considered the equation relative to a fixed flat spacetime. Could it happen that if we curve the space, its curvature could account for the field energy contribution leaving the good old Laplace equation undisturbed and thereby the inverse square law.

The only possible way out of the contradiction is again that gravity must curve space (spacetime) and it can only be described by its curvature. As before then the Einstein equation would follow.

In a simple minded fashion, we can argue as follows. Let M_0 be the bare non gravitational mass of a particle as measured at infinity with vanishing gravitational field energy. At any finite radius, R, in addition it would also have gravitational field energy, and so we write

$$M(R) = M_0 - M^2/2R \tag{5}$$

which when solved for $M(R)$ gives

$$M(R) = -R + \sqrt{r^2 + 2M_0 R} \tag{6}$$

This shows that $M(R)$ vanishes as $R \to 0$ and tends to M_0 at infinity. That means as $R \to 0$, M_0 is completely eaten up by the negative gravitational field energy. If the particle has electric charge, there will remain residual mass proportional to electric charge due to electric field energy. This simple argument does indeed give the right result as obtained by the rigorous calculations [7]. The critical point that emerges is the fact that when gravitational field energy is included with the total mass and not the bare mass participating in the interaction, the total mass remains always finite. Even when rigorous exact calculation is done, this feature remains true and hence it should lead to the same result.

The important point to note is that the rigorous consideration does not invalidate this critical point and hence the result obtained here, save for some matter of detail, would remain true and valid on sound physical consideration as well [6]. This is not however the case for the escape velocity argument for black hole and nor for the equipartition between the Compton length and the Schwarzschild radius for the Planck length.

All this is because of the unique and bizarre property of gravitational field. Its charge is rather a very subtle issue. It is of two kinds; one localizable non gravitational energy while the other non localizable field energy. It is the former which is like electric charge we know about while the latter is completely new and unique to gravity. The latter could honestly be described only through the space curvature [8] and consequently gravitational field by spacetime curvature. Now the most pertinent question that arises is that non gravitational matter fields can be by prescription kept confined to, say 3-space/brane, could we do the same to gravitational field? Could gravity remain confined to 3-space or be free to propagate in higher dimensions as well? This is the question that refers to yet unexploited aspect of gravity.

The field equation for gravitation as derived above does not refer to any dimension of space and would hence be valid for all dimensions. It is a truly universal equation. In the equation, we can prescribe to confine the matter stress tensor, T_{ab} to the 3-brane but Λ refers to vacuum which cannot obviously be confined to any dimension. Thus gravity can

not be confined to any dimension instead it freely propagates in all dimensions. This is purely a classical argument without any reference to string theory which requires higher dimensions. We would like to argue that even from classical standpoint, gravity is indeed a higher dimensional interaction.

V. THE QUANTUM WORLD

We rode on light to come to the relativistic world from the classical world. Once again let us ride on light. We incorporated light in the mechanics by treating it as a zero mass particle. Light also propagates as a wave and its motion is determined by the wave vector. Anything that moves must carry energy and momentum which are described by the 4-momentum vector, P_a. Thus a wave, which is fully characterized by a 4-wave vector, k_a should also have a 4-momentum vector associated with it describing the energy and momentum it carries along. There cannot exist two independent 4-vectors characterizing the motion of a wave. The only sensible thing that can then happen is that the two vectors be proportional, $P_a = hk_a$ which would then readily lead to the well-known relation, $E = h\nu$ relating wave's frequency with the energy it carries. This should be universally true, giving the quantum law with h being the universal constant which could be identified with the Planck's constant.

The wave character of motion implies that it can not be localized in any frame. Non localizability essentially means uncertainty in simultaneous determination of the conjugate variables, position and momentum. In other way, it could be viewed that the process of determining one introduces uncertainty in the other. This happens because the energy required in the measurement process (probe's energy) is not negligible compared to the particle's energy. This phenomenon of uncertainty in determining the conjugate variables simultaneously should therefore be universal and true for all particles. We are thus led to the famous uncertainty relation, $(\delta x^i \delta p^j \geq h\delta^{ij})$, which is the key relation of the quantum

world.

Interestingly, it is again the incorporation of light as a zero mass particle or a wave in the mechanics that leads to the basic quantum principle and consequently to the quantum world. The quantum principle is universal and hence according to our general belief and the guiding principle, it should be expressible as a property of spacetime. This has unfortunately not happened despite the quantum theory being over 100 years old. Unlike SR and GR, quantum theory is not complete and I would believe that the completion would come about only when the quantum principle is expressed as a property of spacetime structure. We shall pick up the thread of incompleteness in the next section while looking beyond.

VI. AND BEYOND

We have so far employed the principle of universalization to chart the passage from Newton to Einstein. The key to this course was the existence of zero mass particles in the nature. Their incorporation in mechanics led to SR and their interaction with gravity led to GR. This is how we come to the relativistic world from the classical world. Now comes the question of going "beyond". Does there still remain some unexploited aspect of universalization which could be tapped to go beyond? The distinguishing feature of the relativistic world is its anchoring on the most fundamental structure - spacetime. SR binds space and time while GR impregnates it with dynamics of gravitational field. Gravity ceases to be a force as it is completely synthesized in the spacetime geometry which now becomes a physical entity like any other force. On this line of approach, it seems quite clear that the way beyond could only come about by exploiting some aspect of spacetime which has so far remained untapped.

So far we have taken spacetime to be a 4-dimensional continuum which is commuta-

tive;i.e. the commutator $[x^i, x^j] = 0$. The commutativity and dimensionality of spacetime are yet free and we should keep our mind open about them.

Universalization always lead to enlargement of the existing framework. For example, inclusion of light's interaction with gravity lead to the fact that spacetime has to be curved - a passage from flat to curved. In our exploration of "beyond" is to identify the contradiction and then attempt to guess the extrapolation required to resolve the issue.

A. Gravitational world

In the Einsteinian world, spacetime is a $(3+1)$-dimensional manifold and the presence of matter/energy curves it and impregnates it with dynamics of gravitational field. The equation that follows from the curvature of spacetime has no reference to the dimension of spacetime and hence is truly valid in all dimensions. Secondly on the right of this equation, there are two terms, one the stress tensor for non gravitational matter fields and the other is the constant Λ which characterizes vacuum - empty space. The former could be confined by prescription to a particular dimension, say 3-brane but the latter is vacuum which cannot be kept confined to any dimension. That is,the gravitational field is however free to propagate in all higher dimensions even when the matter fields are confined to a 3-brane. Gravity is thus truly a higher dimensional interaction and this conclusion follows from purely a classical consideration without reference to string theory [9].

Let us work up yet another argument for higher dimensions. A dynamics of a physical field cannot be fully determined unless the proper boundary conditions are prescribed. The dynamics of gravitational field is described by the curvature of 3-brane, that is the 3-space should have the proper boundary condition. What could that be? For matter fields confined to 3-brane, Λ vacuum in the higher dimensional bulk space would define the proper bound-

ary condition. The curvatures of the two spacetimes would be related by the well-known Gauss-Codazi equation. For the matter confined to 3-space (3-brane), bulk spacetime would be 5-dimensional and the source for curvature in extra dimension is only Λ. The universe we live in could be thought of as hypersurface or domain wall in the bulk spacetime. Since the matter is assumed to be confined on the 3-space, gravitational field which would propagate in the bulk as well would have Z_2-symmetry in the extra dimension.

The picture that emerges is similar to the braneworld gravity [10,11]. The Gauss - Codazi equation connects the curvature tensors of bulk and brane spacetimes while the Israel junction conditions [12] connect the brane extrinsic curvature with the brane tension and stress tensor. From this results an effective modified Einstein equation on the brane [13] while the bulk satisfies the Λ-vacuum equation (we would not here write the equation and the boundary conditions etc.). The equation on the brane is not closed because it has both local and non-local parts. The former arise from the brane stress tensor and its "square" while the latter from the projection of the bulk Weyl curvature onto the brane, which is trace-free and hence is called dark radiation. Further requiring that gravity though free to move in extra dimension should however remain localized (massless graviton to have ground state on the brane) to the brane where its source sits leads to the bulk $\Lambda < 0$, anti de Sitter spacetime [11,14] (it is a different matter that it is also motivated by the AdS-CFT correspondence). The Newtonian potential gets modified and it has an additional $1/r^3$ term. This is what filters down as the high energy correction to the Newtonian gravity. The question of localization of gravity has also been studied for the FRW brane cosmology and it requires Λ on the brane to be non-negative [15,16]. If localization of gravity is taken as the determining factor for the FRW cosmology, non-negative Λ is a definite prediction of the braneworld gravity.

We would thus like to say that braneworld picture of gravitation naturally arises simply from the universal property. This is quite independent and separate motivation. It is the

universality property which is responsible for gravity being a higher dimensional interaction. We have also enunciated an interesting and novel argument for the self interaction of gravitational field and it being attractive simply by demanding stability of a gravitating system.

B. Quantum gravitational world

In our discussion we have so far come across four physical constants, c, h, G and Λ. All of them are different in character and signify different physical aspects. They are as follows:

• c is the most fundamental of the constants. Recently its six different aspects have been enunciated [18] showing its various avatars. The most profound amongst them is that it represents a symmetry of spacetime. It is a universal spacetime property. None of the others has this distinction.

• h is also represents a universal physical principle but like c it has not yet been synthesized into the structure of spacetime. Anything that is universal should be expressible as a spacetime property. This is the main problem of the quantum theory and we yet have no clue about the solution.

• G is simply the coupling constant of spacetime geometry (gravitational field) with the non gravitational matter fields. It is really the measure of the universal aspect of matter fields which links to spacetime geometry. It is the coupling constant for the universal field in which all matter fields participate. The interaction does indeed become a property of spacetime and it is described by its curvature.

• Λ is the new constant of the Einsteinian gravity. It is the measure of vacuum's coupling to spacetime geometry. Vacuum is by definition universal and hence Λ is indeed a new uni-

versal constant. Unlike all others, there prevails a profound ambiguity about its character as a true universal constant particularly because of the chequered history of its introduction and subsequent uncertain and ambiguous existence. In our derivation of the field equation for gravitation, it follows naturally and is in fact on the same footing as the stress tensor for matter field. It is indeed the stress tensor of vacuum. This is the new prediction of the Einsteinian gravity which anticipates the stress tensor of vacuum fluctuations.

Λ is truly a measure of what could happen to vacuum. At the micro level it connects to the quantum fluctuations while at the large scale it defines the size of the Universe - rather it provides a closure to the Universe. It could be viewed as defining the underlying spacetime substratum as the matter free limit of the universe. The remarkable fact is that it is non trivial and has dynamics which is entirely described by Λ.

Dual role of things is quite characteristic of GR. For instance, gravitational potential in the Schwarzschild solution does the dual role of giving the Newtonian inverse square law as well as curving the space for photons to bend. How could Λ, which is a pure GR creature, therefore escape this distinguishing feature? At one end it could be a measure of quantum vacuum fluctuations while at the other it could source the cosmic acceleration. Could it bind the smallest scale of the Universe with the largest and obtain a profound synthesis? This is the most intriguing and interesting question.

We therefore believe that any attempt to quantum theory of gravity must have to address to Λ in a non trivial manner because it is a true new constant of the relativistic gravity [17]. On the other hand, almost all the attempts peg on the Planck length as the most fundamental quantity. The Planck length is a construct made out of the three constants and it does not follow from any theory or physical principle. Also note that the three constants that make the Planck length are all not on the same footing, for instance c represents the Lorentz symmetry of spacetime while none other has such a fundamental claim. We would

argue that a constant that truly follows from a theory should always have precedence over a construct and hence has to be first addressed.

The only physical argument being advanced for the Planck length is that it represents the equipartition between the Compton wave length and the Schwarzschild radius. All this presumes that the whole framework which defines these lengths remain valid at the energy which is 16 orders of magnitude higher than anything we have known so far. This comparison is supposed to be done against a fixed background, how could that remain valid at such a high energy - spacetime has to be curved at such high energy? This simplistic argument might give the right answer though based on wrong reasoning. We have the famous example of this kind. Laplace and Michell obtained the exact Schwarzschild radius by computing the escape velocity for a photon. We all know that it is wrong.

Let me add one more to this kind of tentative consideration by comparing Λ with the Schwarzschild radius and we obtain the mass scale, $c^2/G\sqrt{\Lambda}$ of the order of 10^{57} grams equivalent to 10^{80} nucleons, the total mass of the Universe. In the relativistic world, we have the three constants which yield to this measure of mass. This is a valid scale of the relativistic framework.

My objection to these considerations is not only because they are tentative and based on invalid premise but more so because they blind one from the real insight. If you accept the escape velocity argument for photon, it closes the inquiry as there is nothing further to inquire into. While its non acceptance should have raised the question whose solution would have naturally ended up in a new theory of gravity, GR. To me the Planck length should have the similar kind of blinding effect and it is perhaps hiding the crucial question leading to a correct theory of quantum gravity.

Let us again follow our natural lead of identifying the contradiction in the existing frame-

work and then seeking its resolution by enlarging the framework. For quantum gravity, the contradiction is, matter, which produces gravity, has at high energy quantum behaviour while the spacetime which describes gravity is inherently continuum. Thus arises the contradiction. How do we bypass it?

Going by our earlier experience, we recall that for accommodating light's motion in mechanics we had to bind space and time into a synthetic whole spacetime, and for light to feel gravity we had to curve spacetime. Now what could we do to spacetime to accommodate quantum behaviour of matter which curves it? We had so far not altered the basic structure of space and time, and have always managed by adding a new property. Could we still invoke some new property of spacetime which lets us resolve the contradiction? What is required is to make spacetime curvature discrete. Could curvature be made quantum yet specetime retaining its continuum character? This is the first question. If yes, that would indeed be very good and comfortable. Otherwise we are left with no other option but to make spacetime itself quantum which would obviously be a very formidable task. The loop quantum gravity precisely does that [19].

Frankly I am totally confused here.

Let us note that the equation for gravitational field has as we have obtained two components on the right, one stress energy tensor of matter and the other of vacuum. The former certainly has the quantum structure at high energy while this will not be the case for the latter. Secondly, the former could be confined to a given dimension, say the 3-brane, while the latter cannot be and hence we have to consider gravity as essentially a higher dimensional field. When we are attempting to quantize gravity, we are in totally new and unfamiliar territory. So far we have done quantization of fields and matter against a fixed spacetime background. Now we have to quantize spacetime against itself. If this is not crazy, it is certainly quite strange and bizarre. Now we have an added new feature that the higher dimensional vacuum would continue to have the continuum structure. Could it

then happen that we should consider quantization of gravity (curvature of 3-brane) in the continuum spacetime of higher dimensional vacuum (anti/de Sitter) spacetime. I am not sure how to implement it but it certainly opens up a new window which is in line with what we have done earlier.

Another way of looking at quantization is to ask for synthesis of h with the spacetime structure. This is because quantum principle is universal and hence it must be expressible like c as a property of spacetime. This will render quantum theory complete on par with the relativity theories, SR and GR. The main feature of the quantum framework is non localizability leading to non locality. Note that incorporation of higher dimensional feature of gravity would naturally lead, as in the braneworld gravity, to non local effects. Perhaps it is this non locality which could be exploited or synthesized with the quantization procedure. Could this make space non commutative which may facilitate quantum behaviour? Howsoever crazy may it all look yet, since we are faced with the most formidable and complex problem, no stone should be left unturned. It may therefore happen that synthesis of h into spacetime also requires G along. That is quantum principle could not be synthesized into spacetime alone but it requires gravity along as an inseparable partner. In other words, the quantum theory cannot be completed in flat spacetime, spacetime has necessarily to be dynamic and hence curved. This seems quite natural for the synthesis being sought could only occur at very high energy where spacetime has to be dynamic and curved.

Theory of quantum gravity/spacetime is therefore required for completion of quantum theory as well and which would have to include gravity along.

So far almost all the attempts to quantum gravity have been anchored on the Planck length. In the string theory, quantization is done in higher dimensional flat space and GR together with other fields appear as the low energy effective theory in 4 dimensions. We would rather argue that higher dimensions cannot be flat, they should at least contain Λ

hence string theory should manipulate at least the anti-de Sitter space. The background dependence of the programme is being recognized as one of the major weaknesses of the string theory approach. On the other hand the loop quantum gravity programme does however deal with curved spacetime but restricted to 4-dimensions [19]. We believe that this programme should in some manner have to be supplemented to incorporate higher dimensional nature of gravity.

So far the two main approaches to quantum gravity have remained quite separate and distant from each-other. It is perhaps time that the two should tend to converge. They perhaps address the complimentary aspects of gravity in their framework and asymptotically we should be able to understand the relation between them.

Going by our adherence to universalization and its proper expression in spacetime property as the abiding guiding principle, we argue that gravity is intrinsically higher dimensional field as much as it could only be described by curvature of spacetime. While its basic source, matter fields can remain confined to 3-brane but the field can propagate off the brane. The dynamics of the field in bulk is solely determined by Λ and spacetime there can continue to have the usual continuum character. It has to be quantum on the brane. As shown for the braneworld gravity, the field on the brane has non local aspect. Non locality is a distinguishing feature of quantum theory. Could this incorporation of non locality on the brane facilitate quantization of gravity? On the face of it, this approach would actively involve both Λ and h along with of course c and G. This is precisely what we had asked for that both Λ and h should be involved in quantum gravity. The only other aspect of spacetime which remains still free is commutativity. We could bring in non commutativity if required. This is just a suggestion which is prompted by our general principle of universalization which has so far been reliable and insightful.

In the above I have argued hopefully convincingly the following points:

(a) Λ is not only a true new constant of the relativistic gravity but is the measure of the dynamics of vacuum and which cannot be confined to any specific dimension.

(b) We have also shown that gravity is the unique universal field. We have derived the Einstein equation simply appealing to the universal character of the field.

(c) In an innovative way we have shown why gravity is attractive and is inherently higher dimensional and could only be described by the curvature of spacetime.

(d) It is the completion of the quantum theory which naturally asks for a quantum theory of spacetime and hence of quantum gravity. The synthesis of quantum with spacetime could only occur when gravity is also included. That is spacetime can attain quantum structure only at high energy which would necessarily render spacetime dynamic. For gravity, Λ is unshakable and hence quantum gravity has to in some way involve both h and Λ.

(e) We make a new proposal which takes into account higher dimensional character of gravity and also the fact that vacuum part (bulk spacetime) could continue to have the continuum structure. Synthesizing this with the quantum character of the 3-brane space is the challenge. This approach would involve both h and Λ quite naturally. This is the feature which we had set out for a theory of quantum gravity.

I hope that the above discussion would perhaps open up a new perspective and insight which may turn out to be illuminating.

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